

Technical And Economic Studies of Regional Transition Strategies Toward Widespread Use of Hydrogen Energy

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Presented at the

2004 DOE Hydrogen, Fuel Cells and
Infrastructure Technologies Program Review

Philadelphia, PA

May 27-29, 2004

Project Objectives

- **Assist the DOE in identifying promising paths for developing hydrogen infrastructure.**
 - Develop new simulation tools to evaluate alternative pathways toward widespread use of hydrogen under various demand scenarios and regional conditions.
 - Understand which factors are most important in finding viable transition strategies.
 - Develop “rules of thumb” for future regional hydrogen infrastructure development.
 - Conduct regional case studies of H₂ infrastructure transitions
 - Work with H₂A core group to develop models of hydrogen delivery systems.

Budget FY'04

\$130,000

DOE Technical Barriers and Targets for H₂ Delivery Systems

- **Technical Barrier:**

- *Lack of Hydrogen Carrier and Infrastructure Options Analysis.* “Analysis is needed to understand the advantages and disadvantages of various approaches.”

- **Technical Target:**

- “Perform delivery infrastructure analysis to define cost-effective, energy efficient, and safe infrastructure..for introduction and long term use of hydrogen for transportation and stationary power.”

Technical Approach

- ***Develop new simulation tools to assess alternative transition strategies toward widespread use of H₂ under various demand scenarios and regional conditions.***
 - Develop **engineering/economic models** of hydrogen energy system components: H₂ demand, H₂ production systems, H₂ transmission and distribution, H₂ refueling stations, CO₂ sequestration.
 - Use **Geographic Information System (GIS)** data to study spatial relationships between H₂ demand, supply, primary resources, CO₂ sequestration sites, and existing infrastructure in particular region.
 - Explore use of various techniques (**GIS analysis, mathematical programming**) to find the lowest cost strategy for building a widespread H₂ energy system. Given a specified H₂ demand and resources for H₂ production, design a system to deliver H₂ to users at the lowest cost. Examine which transition paths give the lowest overall cost over time.
 - Carry out **regionally specific case studies** of H₂ infrastructure development, involving multiple H₂ plants, multiple H₂ demand sites, using GIS data.
- ***H2A: Work with DOE's team of hydrogen system analysts to develop "base case" data for hydrogen delivery systems***

Project Safety

- N.A. This project does not involve experimental work or hardware demonstrations.

Project Timeline

7/02 - 8/03; 4/04-9/04

10/04-4/06

Phase I	Phase II
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Phase I :

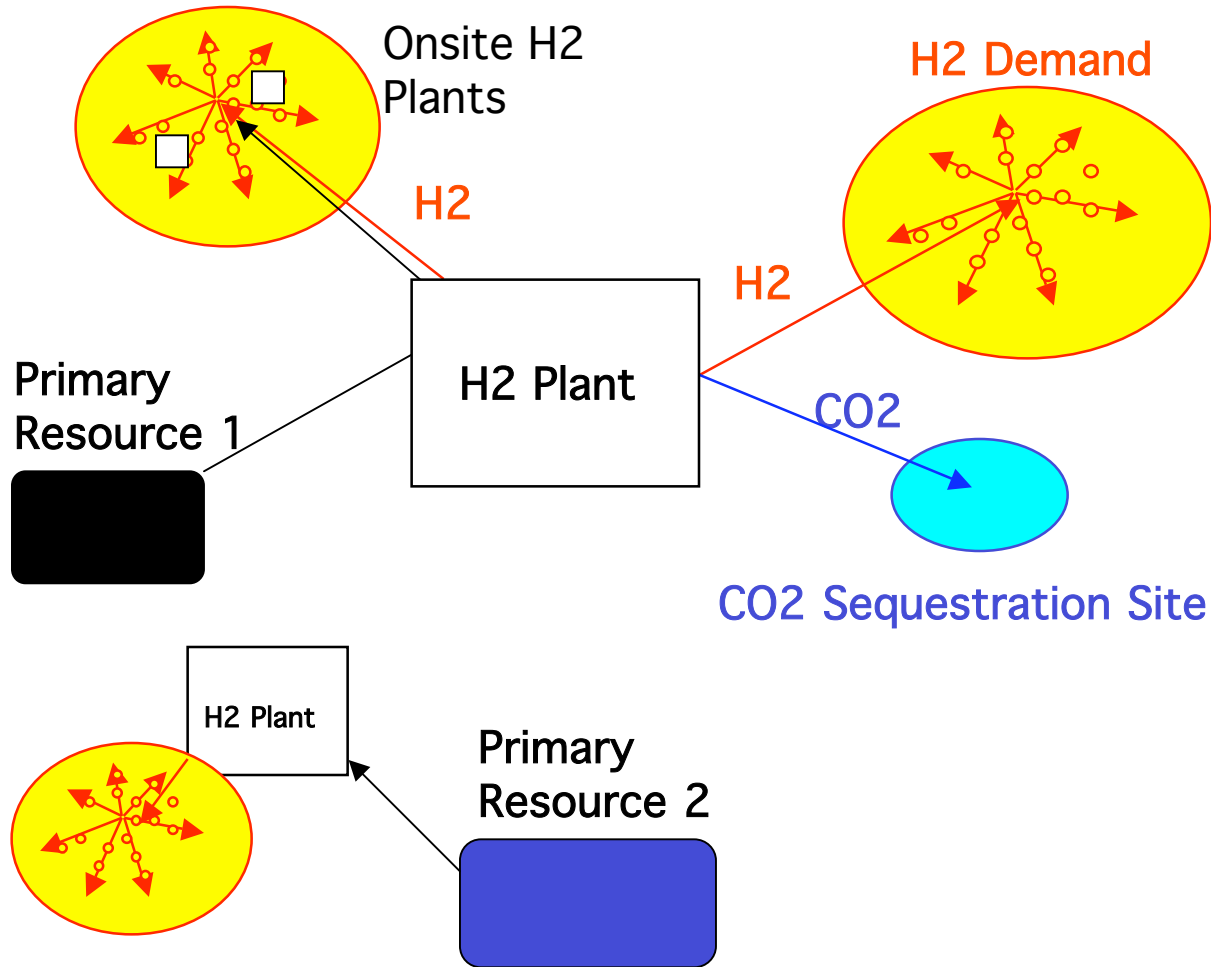
- Develop simulation tools to study regional hydrogen transitions
 - Model H₂ demand spatially and over time
 - Implement Engineering/economic models of H₂ technologies
 - Develop GIS Maps of potential resources for H₂ production
 - Develop GIS Data base for studying hydrogen supply and demand
 - Develop optimization methods to design lowest cost system connecting supply and demand, and find lowest cost transitions
- Work with H2A group on delivery analysis

Phase II:

- Conduct case studies of regional transitions

Modeling Regional Hydrogen Infrastructure Development

What is the best system for producing and delivering H_2 to serve a growing regional demand?



H₂ Supply Cases to be Analyzed

- Centralized, large-scale production of H₂ from:
 - Coal gasification w/ and w/o CO₂ sequestration
 - Natural gas w/ and w/o CO₂ sequestration
 - Biomass gasification
- Distributed production of H₂ at refueling sites from:
 - Natural gas reforming
 - Electrolysis using off-peak power
- Delivery via truck (compressed gas or liquid); gas pipeline.
- For fossil H₂, consider disposal system for CO₂.

Technical Accomplishments (1)

Model H₂ demand spatially over time

Implement simple method using GIS data



Yr 1



Yr 5



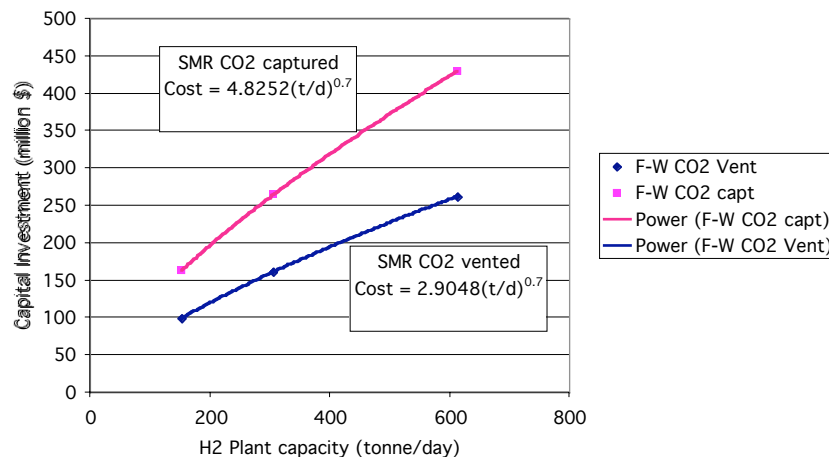
Yr 10

Highlights where concentrated H₂ demands grow first,
magnitude and geographic density of the demand
=> best supply option

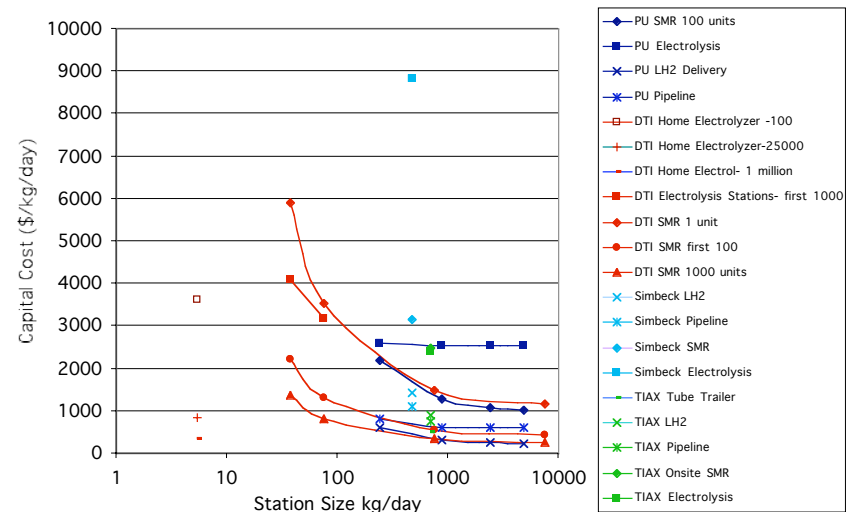
Technical Accomplishments (2)

Implement Engineering/economic models of H₂ technologies (production, storage, distribution and refueling systems) vs. scale & energy prices

Capital Cost of H₂ Plants Using Steam Methane Reforming with and without CO₂ sequestration versus plant capacity



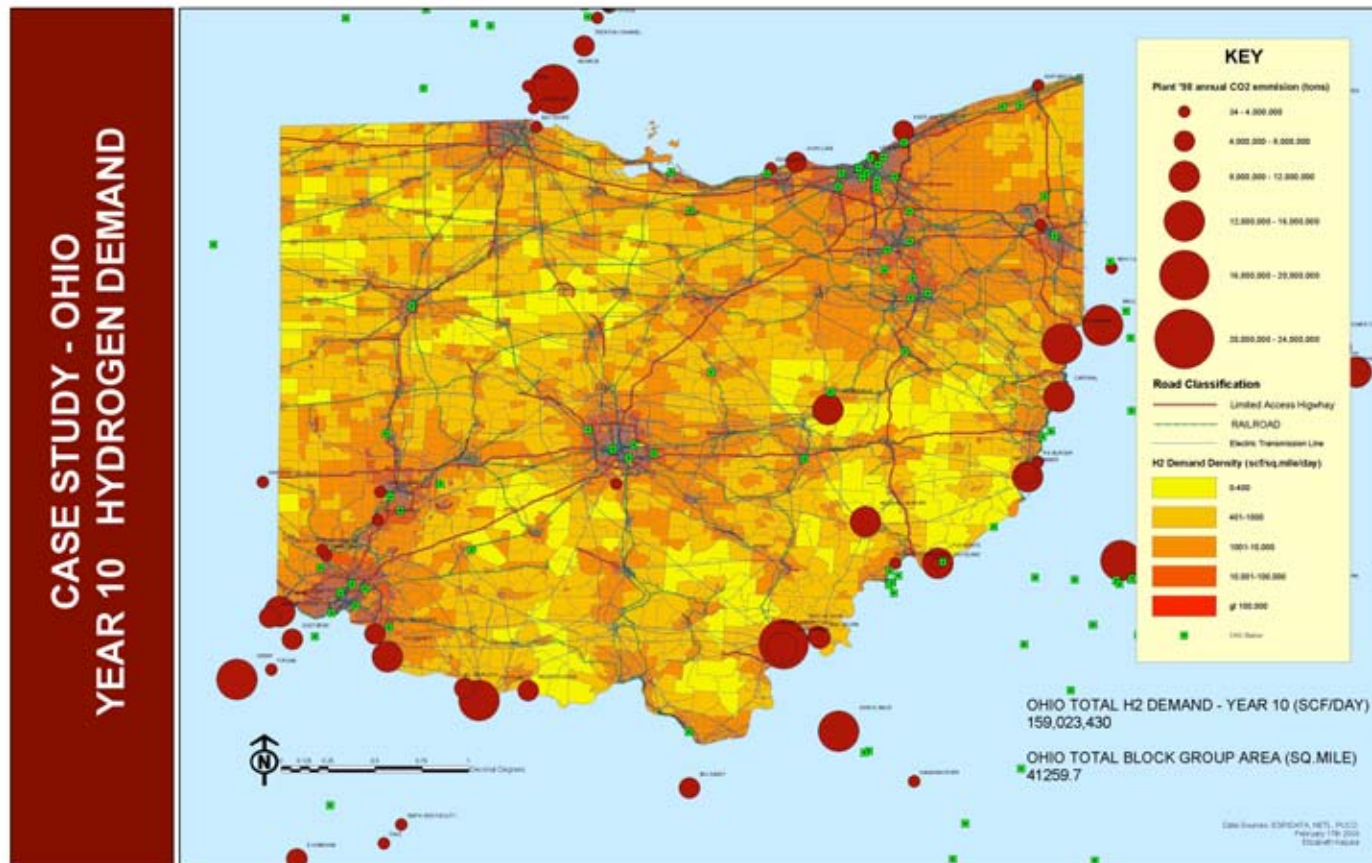
Capital Cost of Hydrogen refueling Stations v. Size



These estimates are being updated to reflect new estimates from the H₂A project and the NAS study

Technical Accomplishments (3)

Develop GIS Maps of potential resources for H₂ production, existing infrastructure; GIS Data base for studying H₂ supply and demand



Explore optimization methods to design lowest cost system connecting supply and demand, and find lowest cost transitions

First step: simple, analytic model to design supply to meet a specified demand (steady-state)

- Estimate infrastructure costs as a function of a small number of variables embodying averaged and/or simplified information about:
 - H₂ markets (fraction of H₂ vehicles in fleet, station size and coverage)
 - Geographic factors (idealized model of city, size and geog. density of demand)
 - Cost and performance of H₂ technologies (vehicles and infrastructure)
- Compare H₂ infrastructure cost (\$), levelized H₂ cost (\$/kg) for various supply options

Participation in H2A group

- Recently, DOE and NREL convened H2A, a group of analysts studying hydrogen energy systems. Their goal is to produce a credible, well-documented set of information on hydrogen production, delivery and forecourt refueling technologies and options.
- **FY'04 Accomplishments**
 - Lead role in H2A team analyzing hydrogen delivery infrastructure
 - Developed information on alternative pathways for delivering hydrogen to consumers
 - Developed base case scenarios for hydrogen delivery.
 - Close collaboration with researchers at DOE, NREL, Argonne on analyzing delivery options
 - Presentation at the NHA Analysis symposium on delivery team's work, April 2004.

Interactions and Collaborations

- UC Davis Hydrogen Pathways Program (multi-disciplinary research program with 15 industry and government co-sponsors)
- NETL (fossil H₂ systems w/CO₂ sequestration)
- Princeton University (H₂ systems)
- H2A Delivery Group
 - DOE
 - NREL
 - Argonne National Laboratory
 - TIAX
 - DTI
 - H2A Key Industrial Collaborators: (Praxair, Air Products and Chemicals, BOC, Chevron Texaco, Exxon Mobil, BP)

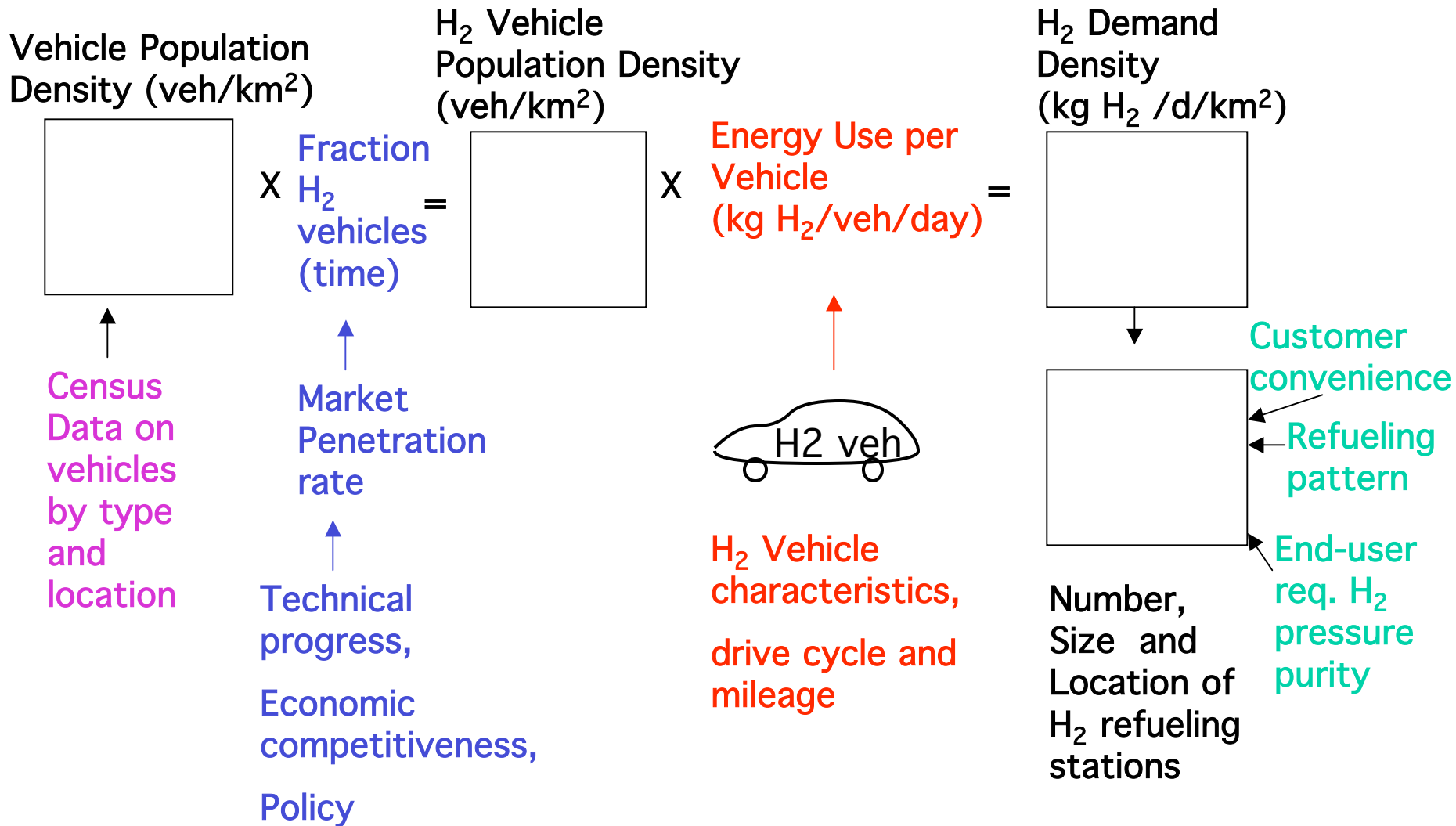
Responses to Previous Year's Reviewers

- This project was not reviewed last year

Future Work

- **Remainder of Phase I (5/04-9/04)**
 - Develop simulation tools to study regional H2 transitions
 - Update hydrogen energy system component cost and performance models to reflect new data available from H2A
 - Compare hydrogen demand models with other work in the literature and ongoing within DOE
 - Further develop mathematical optimization methods to find lowest cost infrastructure solutions.
 - Develop GIS data base for studying H2 infrastructure in the Mid-west including natural gas steam reforming and coal power plant supply options
 - Continue work with H2A group on delivery analysis
- **Phase II (10/04-4/06)**
 - Add capability to model renewable hydrogen
 - Conduct geographic specific case studies of hydrogen infrastructure development

CREATING A H₂ DEMAND MAP



“Base Case” H2A Delivery Scenarios

Market Type	Early Fleet Market (1%)	General Light Duty Vehicles: Market Penetration		
		Small (10%)	Medium (30%)	Large (70%)
Metro	X	X	X	X
Rural			X	
Interstate			X	